

Arbuscular mycorrhizal associations in different forest tree species of Hazarikhil forest of Chittagong, Bangladesh

P. P. Dhar • M. A. U. Mridha

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Abstract: Biodiversity of arbuscular mycorrhizal (AM) colonization and AM fungal spores were studied in the roots and rhizosphere soils of *Acacia catechu* (L.f.) Wild., *A. mangium* Willd., *Anthocephala cadamba* Miq., *Artocarpus chaplasha* Roxb., *Chickrassia tabularis* A. Juss., *Swietenia macrophylla* King., *Tectona grandis* L. from plantations; *Albizia procera* (Roxb.) Benth., *A. falcataria* L., *Alstonia scholaris* (L.) R. Br., *Aphanamixis polystachya* (Wall.) Parker., *Hydnocarpus kurzii* (King.) Warb., *Heynea trijuga* Roxb., *Lagerstroemia speciosa* (L.) Pers., *Messua ferrea* Linn., *Podocarpus nerifolia* Don., *Swintonia floribunda* Griff., *Syzygium fruticosum* (Roxb.) DC., *S. grandis* (Wt.) Wal. from forest and nursery seedlings of *A. polystachya*, *A. chaplasha*, *Gmelina arborea* Roxb. and *S. cumini* (L.) Skeels from Hazarikhil forest, Chittagong of Bangladesh. Roots were stained in aniline blue and rhizosphere soils were assessed by wet sieving and decanting methods. The range of AM colonization varied significantly from 10%–73% in the plantations samples. Maximum colonization was observed in *A. mangium* (73%) and minimum colonization was observed in *C. tabularis* (10%). Vesicular colonization was recorded 15%–67% in five plantation tree species. The highest was in *A. cadamba* (67%) and the lowest was in *T. grandis*; *A. chaplasha* and *C. tabularis* showed no vesicular colonization. Arbuscular colonization was recorded 12%–60% in four plantation tree species. The highest was in *A. mangium* (60%) and the lowest was in *A. cadamba*. Roots of *Artocarpus chaplasha*, *C. tabularis* and *T. grandis* showed no arbuscular colonization. Among 12 forest tree species, nine tree species showed AM colonization. The highest was in *A. falcataria* (62%) and the lowest was in *S. fruticosum* (10%). Significant variation in vesicular colonization was recorded in seven forest tree species. The highest was in *H. trijuga* (52%) and the lowest was in *L. speciosa* (18%). *Hydnocarpus kurzii*, *M. ferrea*, *P. nerifolia*, *S. fruticosum* and *S. grandis* showed no vesicular colonization. Arbuscular colonization was recorded in seven

forest tree species. The highest was in *A. falcataria* (60%) and the lowest was in *A. procera* (10%). All the nursery seedlings showed AM colonization and the range was 10%–73%. Vesicles were recorded in *G. arborea* (40%) and *S. cumini* (40%). Arbuscular colonization was recorded in *G. arborea* (100%) and *S. cumini* (100%). Spore population was recorded 77–432/100 g dry soils, 80–276/100 g dry soils, and 75–153/100g dry soils in plantation, forest and nursery, respectively. *Glomus* and *Acaulospora* were dominant genera among the six AM fungi recorded. Significantly positive correlation was observed between AM colonization and AM fungal spore population in Hazarikhil plantation tree species, forest tree species and nursery tree seedlings. The present study showed the biodiversity of root colonization and AM fungi are active in nutrient cycling, survivals and seedling establishment of the plants in the Hazarikhil forest, plantation and nursery.

Keywords: Arbuscular mycorrhizal fungi; root colonization; spore population

Introduction

Hazarikhil forest, a mixed forest of evergreen, semi evergreen and deciduous tree species, is an endangered forest in northern Chittagong, Bangladesh. It has natural forests, plantations and nurseries under the control of Forest Department of the Bangladesh Government. Important indigenous tree species such as *Swintonia floribunda* and *Podocarpus nerifolia* are threatened due to illegal felling and destruction of the forest. Besides, the natural regeneration of these indigenous plants is facing challenges of removal of leaf-litter, cattle-grazing, random firing, etc. As such, community structures and productivity of Hazarikhil forest are decreasing day by day. Hazarikhil forest is under the agroecological zone 29c (AEZ-29c) (FAO 1985). It is characterized by low hills and piedmont soil. The soil is loamy to sandy loam and is of brown hill soil type. The soil is generally or strongly acidic with the pH range of 5.0–6.4. Organic matter varies 2.0%–5.0% in the forest (FAO 1988).

Arbuscular mycorrhizal technology, the most advanced, well-balanced, and eco-friendly biotechnology has been considered world wide for better management, survival and sustainability of the forest tree seedlings in the nutrient deficient soils of the trop-

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P. P. Dhar 

Department of Botany, Dinajpur Govt. College, Dinajpur-5200, Bangladesh. E-mail: partha_66bd@yahoo.com; Phone: 0088-01718-211284

M. A. U. Mridha

Department of Botany, University of Chittagong, Chittagong-4331, Bangladesh.

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ical and subtropical countries (Klironomos et al. 2000; Bever et al. 2001; Burrows and Pfleger 2002a, 2002b; O'Connor et al. 2002). Arbuscular mycorrhizal fungi (AMF), their genetical and functional diversity in the forest ecosystems are of vital importance. Biodiversity of AMF can be decisive for both plant community structures and productivity (Klironomos et al. 2000; Bever et al. 2001; Burrows and Pfleger 2002a, 2002b; O'Connor et al. 2002). Different AM fungal species associated with the roots of different host species are important in influencing regeneration, diversity and the distribution of plant communities (van der Haijden et al. 1998). Moreover, differences in spore production exhibited by different AM fungal species coupled with differential growth promotion and host association might increase the plant diversity through both niche diversification and negative feed back (van der Haijden et al. 1998; Kiers et al. 2000; Bever 2002; Casteli and Casper 2003). Growth increases are usually accompanied by improved plant nutrient content and are attributed to enhanced mineral nutrition (Marschner and Dell 1994). They reduce the soil borne diseases or the effects of disease caused by fungal pathogens (Jalali and Jalali 1991; Singh et al. 2000). Some free-living nitrogen fixing bacterial genera *Azotobacteria*, *Beijerinckia*, *Clostridium*, *Pseudomonas* and *Azospirillum* have been reported to be more active in presence of AM fungi (Brown and Carr 1984; Mohandas 1987). Colonization of AM fungi can improve the drought resistance (Bethlenfalvay et al. 1988), change the elasticity; improve leaf water potentials and maintenance of stomatal openings and transpiration (Auge et al. 1987a, 1987b). Extra radical hyphae of AM fungi play an important role in creating stable soil aggregate structure (Tisdall and Oades 1982; Bethlenfalvay et al. 1988; Miller and Jastrow 1990). There are important interactions between mycorrhizal fungi and free-living microorganisms and specific microbial communities on rhizosphere and rhizoplane regions. Different microorganisms like fungi, plant growth promoting rhizobacteria (PGPRs) etc have been reported to affect the mycorrhizal fungi and vice versa (Kumar et al. 1995). Besides, mycorrhizal fungi stimulate the effects of microbes and plants retrieve the positive effects.

Information on the mycorrhizal status of AM colonization in the forest trees from India are available (Muthukumar and Udaiyan 2000a; Sharma et al. 1986). Reports on mycorrhizal colonization of the different forest tree species of Bangladesh are very limited (Dhar and Mridha 2003, 2005; Rahman et al. 2003). It is important to determine the AM colonization of the tree species and the biodiversity of AM fungi in the forest, plantation and nursery of Hazarikhil for the incorporation of the mycorrhizal fungi into the sustainable forest management, conservation and survival of the forest-tree-seedlings in the nursery (Mridha 2000). The purpose of this study is to understand occurrence of AM fungi, the biodiversity of mycorrhizal colonization and arbuscular mycorrhizal fungi in the rhizosphere soils of different tree species growing in Hazarikhil forests, plantations and nurseries.

Materials and methods

Fine roots and rhizosphere soils of different tree species (*Acacia catechu* (Lf) Wild, *A. mangium* Willd, *Anthocephala cadamba*

Miq., *Artocarpus chaplasha* Roxb., *Chickrassia tabularis* A. Juss., *Swietenia macrophylla* King., *Tectona grandis* L. from plantations; *Albizia procera* (Roxb.) Benth., *A. falcataria* L., *Alstonia scholaris* (L.) R. Br., *Aphanamixis polystachya* (Wall.) Parker., *Hydnocarpus kurzii* (King.) Warb., *Heynea trijuga* Roxb., *Lagerstroemia speciosa* (L.) Pers., *Messua ferrea* Linn., *Podocarpus nerifolia* Don., *Swintonia floribunda* Griff., *Syzygium fruticosum* (Roxb.) DC., *S. grandis* (Wt.) Wal from forests. Rhizosphere soil from plantations and forests were collected with a soil corer from 0–15 cm depth. Entire root systems of the seedlings of *A. polystachya*, *A. chaplasha*, *Gmelina arborea* Roxb. and *S. cuminii* (L.) Skeels from nursery were gently separated to avoid damaging the fine roots and gently washed to remove soil particles, and soaked in distilled water.

Roots were separated and soils were sieved with 2-mm sieve to remove the gravels and other particles. Soils were studied for the assessment of AM fungal spore population by wet sieving and decanting method (Gerdeemann and Nicolson 1963) with some modifications. Soil was mixed with 5 liters of water and a soil water suspension was prepared. The suspension was left for few minutes for settling down of the insoluble particles and it was passed through the ASTM-60, ASTM-100, ASTM-240 and ASTM-400 sieves gradually to extract the spores. The residues on the sieves were spread on Whatman filter paper No.1 on which squares were drawn earlier by intersected lines for convenient spore counting. The filter paper was examined under compound microscope to count the spore population. They were identified according to Morton and Benny (1990) and Schenck and Perez (1992) after mounting on Melzer's reagent and PVLG. Percent genera were calculated (Dhar et al. 2005).

Roots preserved in 5% formalin were washed well to remove the formalin and chopped into 1-cm pieces. Clean root samples were cleared in 10% KOH solution for 10 min at 85–90°C and deeply pigmented roots were treated in 10% H₂O₂ at room temperature for 10 min, stained with 0.05% aniline blue solution at 90°C for 90 min, and then stored in glycerol solution (Phillips and Hayman 1970) with some modifications. A total of 100 segments from each species were examined. Roots segments were observed by a compound microscope at 10×10 magnification. Percent root colonization was calculated (Dhar and Mridha 2003).

Presence of mycelium was regarded as the AM positive and total mycelial colonization was treated as the total AM colonization. The intensity of mycelial, vesicular and arbuscular colonization were recorded as poor, moderate and abundant (Dhar and Mridha 2003). Statistical analyses were calculated using SPSS-11.5 and MS Excel software.

Results

AM colonization

Plantation

As shown in Fig. 1, all the plantation tree species were colonized by AM fungi. Percent AM colonization in different planta-

tion tree species varied significantly as indicated by the ANOVA (DMRT at $p < 0.05$). The range of colonization varied 10–73%. The highest AM colonization was recorded in *A. mangium* (73%) followed by *A. cadamba* (70%), *T. grandis* (55%) and *A. chaplasha* (25%); the lowest was recorded in *C. tabularis* (10%). The data on AM structural colonization in different plantation tree species were presented in Table 1. Percent colonization of mycelium, vesicles and arbuscules were significantly variable. The range of mycelial colonization varied 10%–73%. The highest percent of mycelial colonization was recorded in *A. mangium* (73%) followed by *A. cadamba* (70) and the lowest in *C. tabularis* (10%). Vesicular colonization was observed in five tree species and the range varied 15%–67%. The highest was recorded in *A. cadamba* (67%) followed by *A. mangium* (51%), *A. catechu* (43%), *S. macrophylla* (40%) and the lowest was in *T. grandis* (15%). *A. chaplasha* and *C. tabularis* showed no vesicular colonization. Arbuscular colonization was observed in four plantation tree species. The range of arbuscular colonization was recorded 12%–60%. The highest was recorded in *A. mangium* (60%) followed by *A. catechu* (33%) and *S. macrophylla* (19%). The lowest was recorded in *A. cadamba* (12%). Poor, moderate and abundant intensity were recorded 15%–100%, 14%–41%

and 15%–63% for mycelial colonization, 22%–58%, 22%–100% and 28%–53% for vesicular colonization and 33%–70%, 20%–100% and 30%–47% for arbuscular colonization respectively in the plantation tree species.

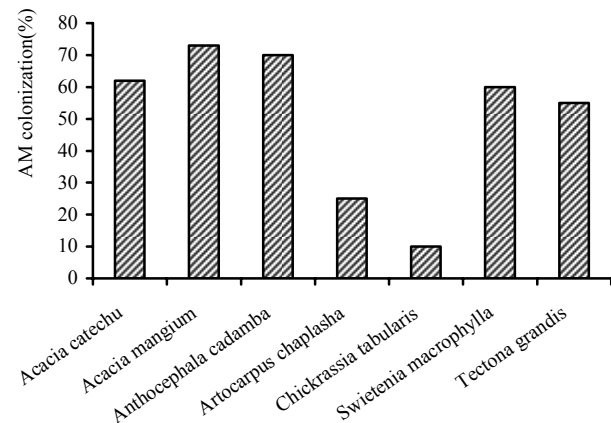


Fig. 1 Arbuscular mycorrhizal colonization (%) in the roots of different plantation tree species from Hazarikhil

Table 1. Biodiversity of AM fungal colonization in the roots of different plantation trees from Hazarikhil.

Species	Total colonization (%)			Mycelium (%)			Vesicles (%)			Arbuscules (%)		
	Mycelium	Vesicles	Arbuscules	P**	M	A	P	M	A	P	M	A
<i>Acacia catechu</i>	62c*	43c	33b	19	18	63	72	--	28	70	--	30
<i>Acacia mangium</i>	73a	51b	60a	32	41	27	25	22	53	33	20	47
<i>Anthocephala cadamba</i>	70b	67a	12d	43	14	43	22	37	41	--	100	--
<i>Artocarpus chaplasha</i>	25f	00f	00e	100	--	--	--	--	--	--	--	--
<i>Chickrassia tabularis</i>	10g	00f	00e	100	--	--	--	--	--	--	--	--
<i>Swietenia macrophylla</i>	60d	40d	19c	15	30	15	58	42	--	37	63	--
<i>Tectona grandis</i>	55e	15e	00e	100	--	--	--	100	--	--	--	--

*Different letters showed significant variation as indicated by DMRT at $p < 0.05$; **P-Poor, M-Moderate, A-abundant

Forest trees

Among 12 different forest-tree species, nine trees showed AM colonization (Fig. 2), with a significant variation of 10%–62%. The highest was in *A. falcataria* (62%) followed by *H. trijuga* (58%), the lowest was in *S. fruticosum* (10%). *Hydnocarpus kurzii*, *M. ferrea* and *P. nerifolia* showed no AM colonization. In nursery, all the tree seedlings showed AM colonization conditions. The data on AM fungal structural colonization in the roots of different forest trees was significantly variable according to the ANOVA (Table 2). The range of mycelial colonization varied 10%–62%. The highest was in *A. falcataria* (62%) followed by *H. trijuga* (58%). The lowest was in *S. fruticosum* (10%). No colonization was observed in *Hydnocarpus kurzii*, *M. ferrea* and *P. nerifolia*. Vesicular colonization was recorded in five tree species and the range of colonization was recorded 18%–51%. The highest was in *H. trijuga* (52%) and the lowest was in *L. speciosa* (18%). Arbuscular colonization was recorded in seven tree species and the range was recorded 10%–60%. The highest and lowest arbuscular colonization was recorded in *A. falcataria* (60%) The lowest arbuscular colonization was in *A. procera* (10%). Poor, moderate and abundant intensity was recorded

10%–100%, 20%–30% and 15%–67% for mycelium; 19%–31%, 33%–100% and 30%–14% for vesicules; 33%–100%, 24%–100% and 21%–62% for arbuscules respectively in the roots of different forest tree species.

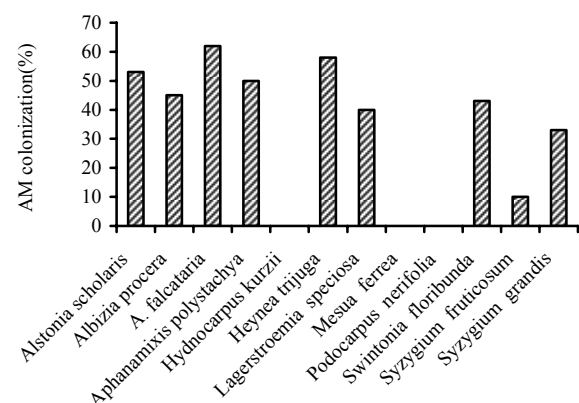


Fig. 2 Arbuscular mycorrhizal colonization (%) in the roots of different forest tree species from Hazarikhil.

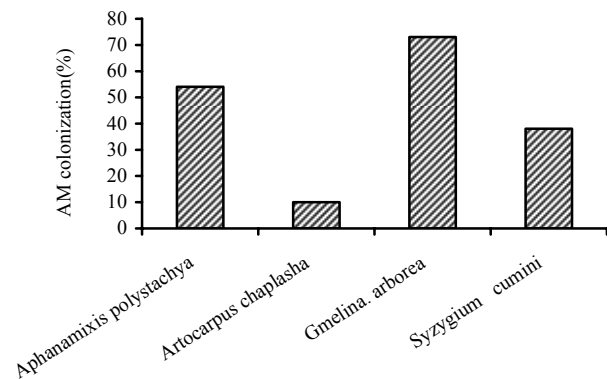
Table 2. Biodiversity of AM fungal colonization in the roots of some tree species of Hazarikhil forest.

Species	Total colonization (%)			Intensity of structural colonization (%)								
				Mycelium			Vesicles			Arbuscules		
	Mycelium	Vesicles	Arbuscules	¹ P	M	A	P	M	A	P	M	A
<i>Alstonia scholaris</i>	53c*	51a	30c	19	13	21	25	45	30	33	24	43
<i>Albizia procera</i>	45e	20e	10e	10	20	15	--	100	--	--	100	--
<i>A. falcata</i>	62a	49b	60a	35	30	35	31	33	36	45	55	--
<i>Aphanamixis polystachya</i>	50d	29d	00f	10	30	60	--	100	--	--	--	--
<i>Hydnocarpus kurzii</i>	00j	00g	00f	--	--	--	--	--	--	--	--	--
<i>Heynea trijuga</i>	58b	52a	38b	40	24	36	19	38	43	34	45	21
<i>Lagerstroemia speciosa</i>	40g	18f	29c	100	--	--	--	100	--	38	--	62
<i>Mesua ferrea</i>	00j	00g	00f	--	--	--	--	--	--	--	--	--
<i>Podocarpus nerifolia</i>	00j	00g	00f	--	--	--	--	--	--	--	--	--
<i>Swintonia floribunda</i>	43f	39c	15d	16	30	54	26	--	74	--	100	--
<i>Syzygium fruticosum</i>	10i	00g	00f	100	--	--	--	--	--	--	--	--
<i>Syzygium grandis</i>	33h	00g	15d	--	33	67	--	--	--	100	--	--

*Different letters showed significant variations as indicated by DMRT at $p < 0.05$; ¹P-Poor, M-Moderate, A-Abundant

Nursery seedlings

Percent AM colonization in the nursery seedlings were presented in the Fig. 3. The range of AM colonization was recorded 10–73%. Arbuscular mycorrhizal colonization varied significantly. The highest was recorded in *G. arborea* (73%) followed by *A. polystachya* (54%) and *S. cumini* (38%). The lowest was in *A. chaplasha* (10%). In the nursery seedlings arbuscular mycorrhizal structural colonization varied significantly (Table 3). The range of mycelial colonization was recorded 10–73%. The highest was in *G. arborea* (73%) followed by *A. polystachya* (54%) and *S. cumini* (38%). The lowest was in *A. chaplasha* (10%). Vesicular colonization and arbuscular colonization were recorded in *G. arborea* (40% and 37%) and *S. cumini* (40% and 25%). Poor, moderate and abundant intensities were recorded 16–100%, 8–55% and 26–76% for mycelium; 00%, 00% and 100% for vesicles and 0–46%, 27–100% and 0–27% for arbuscules in the roots of nursery seedlings.

**Fig. 3 Arbuscular mycorrhizal colonization (%) in the roots of different nursery seedlings from Hazarikhil.****Table 3. Arbuscular mycorrhizal fungal colonization in some tree-seedlings from Hazarikhil Nursery**

Species	Total colonization (%)			Mycelium (%)			Vesicles (%)			Arbuscules (%)		
	Mycelium	Vesicles	Arbuscules	P ¹	M	A	P	M	A	P	M	A
<i>Aphanamixis polystachya</i>	54b*	00b	00c	26	--	74	--	--	--	--	--	--
<i>Artocarpus chaplasha</i>	10d	00b	00c	100	--	--	--	--	--	--	--	--
<i>Gmelina. arborea</i>	73a	40a	37a	16	8	76	--	--	100	46	27	27
<i>Syzygium cumini</i>	38c	40a	25b	19	55	26	--	--	100	--	100	--

Arbuscular Mycorrhizal fungi

Plantation trees

Spore population, biodiversity and percent distribution of AM fungal genera in the rhizosphere soils of different plantation trees were shown in Table 4. All the soil samples of plantation tree species showed AM fungal spores and the spore population varied. Total spore population varied 77%–432/100 g dry soils. The

highest was in *A. catechu* (432) followed by *S. macrophylla* (212), *A. cadamba* (170), *A. mangium* (150) and *C. tabularis* (115). The lowest was in *A. chaplasha* (77). *Glomus* (38%–86%) and *Acaulospora* (12%–25%) were recorded in all plantation soil samples. The highest percent of *Glomus* was recorded in the soils of *A. mangium* (86%) followed by *A. chaplasha* (82%), *S. macrophylla* (76%), *A. cadamba* (68%), *T. grandis* (61%) and *A. catechu* (54%). The lowest was in *C. tabularis* (38%). The highest percent of *Acaulospora* was recorded in the soils of *C. tabu-*

laris (25%) followed by *A. catechu* (23%), *S. macrophylla* (18%), *T. grandis* (17%), *A. cadamba* (15%) and *A. mangium* (14%). The lowest was in *A. chaplasha* (12%). *Sclerocystis* were re-

corded. (4%–12%), *Entrophospora* (5%–10%) and *Gigaspora* (6%–15%) A few spores remained unidentified.

Table 4. Biodiversity of AM fungal spore in the rhizosphere soils of some forest trees from Hazarikhil plantation

Tree species	Spore population	Glm. ² (%)	Scl. (%)	Acl (%)	Ent (%)	Gig. (%)	Scut (%)	Unfd (%)
<i>Acacia catechu</i>	432a*	54f	--	23	10	15	--	7
<i>Acacia mangium</i>	150d	86a	--	14	--	--	--	--
<i>Anthocephala cadamba</i>	170c	68d	--	15	5	12	--	--
<i>Artocarpus chaplasha</i>	77f	82b	4	12	--	--	--	2
<i>Chickrassia tabularis</i>	115e	38g	--	25	--	12	--	25
<i>Swietenia macrophylla</i>	212b	76c	--	18	6	--	--	--
<i>Tectona grandis</i>	169c	61e	12	17	--	6	--	4

*Different letters showed significant variations as indicated by DMRT at $p < 0.05$; ¹P-Poor, M-Moderate, A-Abundant; ²Glm-*Glomus*, Scl- *Sclerocystis*, Acl- *Acaulospora*, Ent- *Entrophospora*, Gig-*Gigaspora*, Scut- *Scutellospora*, Unfd- Unidentified

Forest trees

The spore population of AM fungi in the rhizosphere soils of different forest tree species varied significantly (Table 5), with the range of 35–276/100g dry soil. The highest was recorded in *H. trijuga* (276) and the lowest in *S. grandis* (35). *Glomus* was the dominant fungi genera in the rhizosphere soil samples of all the tree species except for *Anthocephala cadamba*. The percent population of *Glomus* was recorded 30%–100%. The highest

was recorded in *M. ferrea* (100%) and the lowest was in *A. cadamba* (30%). *Acaulospora* was recorded 3%–36% in ten samples. The highest was in *A. cadamba* (36%) and the lowest was in *H. kurzii* (3%). *Sclerocystis* was recorded 3%–55% in six soils. The highest was in *L. speciosa* (55%) and the lowest was in *H. kurzii* (3%). *Entrophospora* was recorded in two soils (5%–15%), *Gigaspora* was in *S. grandis* (11%) only and *Scutellospora* was in the soils of *A. cadamba* (3%) and *S. grandis* (7%). Some spores were unidentified.

Table 5. Biodiversity of AM fungi in the rhizosphere soils of some tree species from Hazarikhil forest

Tree species	Spore population	Glm. ¹ (%)	Scl. (%)	Acl. (%)	Ent. (%)	Gig. (%)	Scut. (%)	Unfd (%)
<i>Alstonia scholaris</i>	130h*	90b	--	6	--	--	--	4
<i>Albizia procera</i>	169e	80c	--	12	5	--	--	3
<i>A. falcata</i>	229c	73e	8	15	--	--	--	4
<i>Anthocephala cadamba</i>	173d	30j	--	36	15	--	3	16
<i>Hydnocarpus kurzii</i>	110i	75d	3	3	--	--	--	19
<i>Heynea trijuga</i>	276a	62f	8	23	--	--	--	7
<i>Lagerstroemia speciosa</i>	140g	40i	55	5	--	--	--	--
<i>Mesua ferrea</i>	80j	100a	--	--	--	--	--	--
<i>Podocarpus nerifolia</i>	148f	72e	--	24	--	--	--	6
<i>Swintonia floribunda</i>	272b	47g	13	33	--	--	--	7
<i>Syzygium fruticosum</i>	50k	100a	--	--	--	--	--	--
<i>S. grandis</i>	35l	45h	15	21	--	11	7	2

* Different letters showed significant variation as indicated by DMRT at $p < 0.05$; ¹ Glm-*Glomus*, Scl- *Sclerocystis*, Acl- *Acaulospora*, Ent- *Entrophospora*, Gig- *Gigaspora*, Scut- *Scutellospora*, Unfd- Unidentified.

Table 6. Biodiversity of AM fungal spores in the rhizosphere soils of different tree-seedlings from Hazarikhil Nursery

Tree species	Spore population	Glm (%) ¹	Scl (%)	Acl (%)	Ent (%)	Gig (%)	Scut (%)	Unfd (%)
<i>Aphanamixis polystachya</i>	133c*	40c	--	--	--	60	--	--
<i>Artocarpus chaplasha</i>	75d	20d	47	33	--	--	--	--
<i>Gmelina arborea</i>	153a	43b	9	39	--	--	--	9
<i>Syzygium cumini</i>	142b	71a	--	26	3	--	--	--

* Different letters showed significant variation as indicated by DMRT at $p < 0.05$; ¹ Glm-*Glomus*, Scl- *Sclerocystis*, Acl- *Acaulospora*, Ent- *Entrophospora*, Gig- *Gigaspora*, Scut- *Scutellospora*, Unfd- Unidentified

Nursery seedlings

Rhizosphere soils of Hazarikhil nursery seedlings produced AM fungal spores with significant variation in the population (75–153/100g dry soil). The lowest population was observed in

A. chaplasha and the highest in *G. arborea*. *Glomus* and *Acaulospora* were the dominant AM fungal genera in the nursery soils. *Glomus* was recorded 20%–71% in all samples. *Acaulospora* was recorded 26%–39% in three samples. *Sclerocystis* was re-

corded in two samples (9%–47%). *Entrophospora* and *Gigaspora* were found in *S. cumini* (3%) and *A. polystachya* (60%) respectively. *Scutellospora* was not observed in nursery.

Discussion

The present study confirms the occurrence of AM fungi and the AM colonization in the Hazarikhil forest. However, *H. kurzii*, *M. ferrea* and *P. nerifolia* from forest area showed no AM colonization. Total percent AM colonization, AM structural colonization, AM fungal spore population and the distribution of AM fungi were significantly variable in the plantation tree species, forest tree species and nursery seedlings. Similar variations in AM colonization and spore population and the distribution of AM fungi were reported for different forests like peat swamp forest (Tawaraya et al. 2003), heath forest (Moyersoen et al. 2001), tropical forests of India (Muthukumar and Udaiyan 2000a; 2000b; Mohonkumar and Mahadevan 1987; Neeraj et al. 1991; Ragupathy et al. 1990; Sengupta and Chowdhuri 1990), rain forests of South Cameroon (Onguene and Kuyper 2001).

Wide variation in the percent colonization, intensity of structural colonization, percent population and the distribution of AM fungal spores may be the results of variable host susceptibility (Mehrotra 1998), diverse type of AM fungi in the rhizosphere soils of individual plant species, host efficiency in soil resource capture and utilization (Koide 1991; Clark and Zeto 2000), soil types and quality (Raman and Gopinathan 1992), root morphology (Hetrick 1991) and mycorrhizal dependency of different host plants and other edapho-climatic factors (Fontenla et al. 1998; Abbott and Robson 1991). The involvement of intercellular or intracellular mycorrhizal associations or association of more than one mycorrhizal fungus with single host tree might be attributed to their physiological, ecological, and genetical variability (Sharma et al. 1986). Seasonal sporulation of AM fungi, seasonal variation in the development of host plants (Sutton and Barron 1972) and the nutrient availability in the soils (Louis and Lim 1987) might cause variation in AM colonization, spore population and distribution of AM fungal spores. The absence of AM colonization in *H. kurzii*, *M. ferrea* and *P. nerifolia* might explain the non-mycotrophic nature of the hosts or preventing from loss of Carbon source. Presence of AM fungal spores in their rhizosphere soil indicated the involvement of AM fungi in symbiosis of these plants in emergency. However, more extensive studies are needed to confirm the non-mycotrophic nature of the plant species. Many researchers have reported the occurrence of mycorrhizas in several tree species, which were considered earlier as non-mycorrhizal (Muthukumar and Udaiyan 2000a; Neeraj et al. 1991; Meney et al. 1993). In the plantation samples, the biodiversity of AM colonization and AM structural colonization were relevant to the observations of Rahman et al. (2003) and Dhar and Mridha (2003, 2005).

Root systems and root physiology of the tree species are adapted to maximize the nutrient uptake capacity in low-resource environment and the role of AM fungi was to increase the uptake capacity of the active zone (Cruz et al. 2004) of the root systems.

In the soils where nutrient deficiency becomes limiting factor, the host plant responded to the symbiosis of arbuscular mycorrhiza (Bhatia et al. 1996). Organic matter, which serves as a nutrient sink for the plants, could also regulate the intensity of mycorrhiza (Bhatia et al. 1996). Soil disturbance has also considerable influence on the root colonization and the AM fungal biodiversity. In an undisturbed ecosystem, higher spore population was quite natural and the diversity was higher in native undisturbed forests than the disturbed and replanted areas (Sieverding 1991; Alexander et al. 1992; Moriera-souza et al. 2003).

The AM fungal spore number recorded in the present study is greater than the previously reported number from tropics (Khan 1974; Parvathi et al. 1984; Al-Garni and Daft 1990; Jasper et al. 1990; Neeraj et al. 1991), which contradicts the view that perennial ecosystems contain fewer spores than field subjected to annual disturbance (Hayman 1982). The features favoring the higher population may either be the conducive to edaphic conditions for sporulation like low nutrient status, high aeration and optimum moisture or the undisturbed conditions of the soils which allowed sufficient time for the building up of mycorrhizal spores (Chulan and Omar 1991). A few tree species showed no AM colonization; anyhow spore population, biodiversity of AM fungi and the distribution of AM fungi in their rhizosphere soils were observed. Different under-shrubby plants might cause the richness of AM fungal spores in the rhizosphere soils of non-host tree species.

AM fungal distribution, AM colonization and mycorrhizal efficiency might be influenced by many soil factors such as soil pH and soil humidity level (Abbott and Robson 1991; Moreira-Souza et al. 2003). Sharma et al. (1986) reported that the occurrence of AM species in the subtropical forest ecosystems of Meghalaya (India) are controlled to a great degree by the soil pH, organic matter, moisture and nutrients status of forest floor. The soil pH is known to control the availability of nutrients from the soils to plants thereby regulating the status of mycorrhiza (Baylis 1967). Moreira-Souza et al. (2003) also reported higher spore population in their study. The genetic diversity of AM fungi might be responsible to the variation in their pattern of production and colonization.

Patterns of spore production and spore quantity are closely related to the plant phenology, root phenology and root production (Brundrett 1991). Every life history of a mycorrhizal fungus is mainly dependent upon plant roots. Because plant roots directly influence spore germination, germination rate, direction of germ tubes, hyphal branching, recognition of the host, root penetration, establishment intensity of colonization and growth of hyphae into soils and sporulation of the AM fungi etc. (Bhatia et al. 1996). There are significant differences in organic chemicals and volatile compounds between the roots of different plants. Different volatile compounds such as organic acids and alcohol could affect the activity and the life cycles of the AM fungi in the natural ecosystems.

There were significantly positive correlation between AM colonization and AM fungal spore population in plantation ($r=0.434$ at $p<0.05$), in forest ($r=0.621$ at $p<0.01$) and nursery

($r = 0.894$ at $p < 0.01$). Many researchers found positive relationship between AM colonization and spore population. Louis and Lim (1987) found higher root colonization followed higher number of spores in surrounding soils. However, Fontenla et al. (1998) found low frequency of colonization when the number of spore was high and vice versa. Many authors reported no significant relationship between AM colonization and spore population (Dhar and Mridha 2003; Dhar et al. 2005). It might be due to the different gradients by soil and the strong effect of plant factors on the formation, function and adaptation of the fungus to the respective soil conditions.

In the investigated six established genera, five genera were isolated from the rhizosphere soils of different forest tree plants. *Glomus* was the dominant genera, followed by *Acaulospora*. This finding is in agreement with the previous results reported by Muthukumar and Udaiyan (2000a, 2000b), Thapar and Khan (1985), and Sharma et al. (1986). They described the wider adaptation of the taxon in varied soil conditions. Pattern of spore population of *Glomus* might cause the dominancy of the genus. Spores of *Glomus* grow in bunch while others grow singly. The abundance of *Acaulospora* might illustrate the soil pH of Hazarikhil as *Acaulospora* are often available with acidic soils (Morton 1986; Abbott and Robson 1991). There might be great diversity of mycorrhizal fungi often associated with the same plant (Allen and Boosalis 1983). Different life-duration of the different host plants might be the controlling the species composition of AM fungi (see Muthukumar and Udaiyan 2000a). Disturbance might also be responsible for distribution of AM fungi (Jasper et al. 1989). Climatic seasons are more influential of species richness and abundance of mycorrhizal spores. Mycorrhization of forest plants has recently been considered as the substitute of chemical fertilizers and pesticides regarding environment pollution and disease control for better management of tropical forests. More studies are being emphasized to select the suitable indigenous AM fungal strains for the establishment and managing the forests, plantation and nurseries and to make the foresters, entrepreneurs and people conscious about mycorrhiza as a tools to maintain and manage the forests environmentally friendly.

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